Journal of the Royal Society of Western Australia, 83: 251-254, 2000

Hydrodynamics of Leschenault Inlet, Western Australia

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Abstract

A mathematical model of Leschenault Inlet and Koombana Bay was developed using finite element techniques to describe the circulation patterns in Leschenault Inlet under the influence of a variety of tidal, river inflow and wind conditions. Simulations included long term tidal characteristics, typical summer ebb and flood conditions, typical winter ebb and flood conditions and typical summer conditions with the influence of an afternoon sea breeze coinciding with a flooding tide. Tidal constituents for the Port of Bunbury, south of Leschenault Inlet provided the tidal boundary condition data for the model. The port is influenced by predominantly diurnal tides (one tide per day) with a mean spring tidal range 0.5 m. A slightly higher than mean spring tide was used for all short period simulations with a tidal amplitude of 0.3 m about mean sea level. Additionally, the four main constituents from Bunbury (M2, S2, O1, K1) were used to generate a long period of tides to assess the effect of the spring and neap tidal ranges on water levels in Leschenault Inlet. Results indicated a significant attenuation of the ocean tidal range in the inlet as well as a 4- to 7-hour phase lag for high and low water between the ocean and the inlet. These characteristics are a consequence of the hydraulic restriction presented by "The Cut". Mean water level in Leschenault Inlet was also found to be influenced by river flow and was generally higher during the winter months when flows from the Preston, Ferguson, Collie and Brunswick Rivers are higher. Circulation patterns in the inlet were found to be similar for summer and winter conditions. The afternoon sea breeze had only a minor effect on circulation patterns in Leschenault Inlet. The model has not been verified against measured current data in the inlet. Nevertheless, it provides a useful tool for comparing different tidal, wind and river flow scenarios.

Keywords: Leschenault Inlet, south-western Australia, estuary, hydrodynamics, mathematical modeling.

Introduction

Leschenault Inlet is a large coastal lagoon located just north of Bunbury, Western Australia. It is connected to the Indian Ocean by a narrow artificial passage known as "The Cut". Water levels in the inlet are influenced by tidal variations in Koombana Bay and surface drainage water from the Collie and Brunswick Rivers to the east and the Preston and Ferguson Rivers to the south. Flows in these river systems are highly seasonal.

This paper describes the circulation patterns in Leschenault Inlet under the influence of a variety of tidal, river inflow and wind conditions.

Model Development

A mathematical model of Leschenault Inlet and Koombana Bay has been developed using finite element techniques from the RMA suite of software (King 1997). The finite element network is shown in Fig 1, with detail at "The Cut" shown in Fig 2.

The model has not been verified against measured data, nevertheless it provides a useful tool for comparing different tidal, wind and river flow scenarios.

Simulations presented herein are: long term tidal characteristics, typical summer ebb and flood conditions, and typical winter ebb and flood conditions.

There are published tidal constituents (*i.e.* the harmonic components of the tides: M2 = main lunar constituent for a semidaily tide, S2 = main solar constitu-

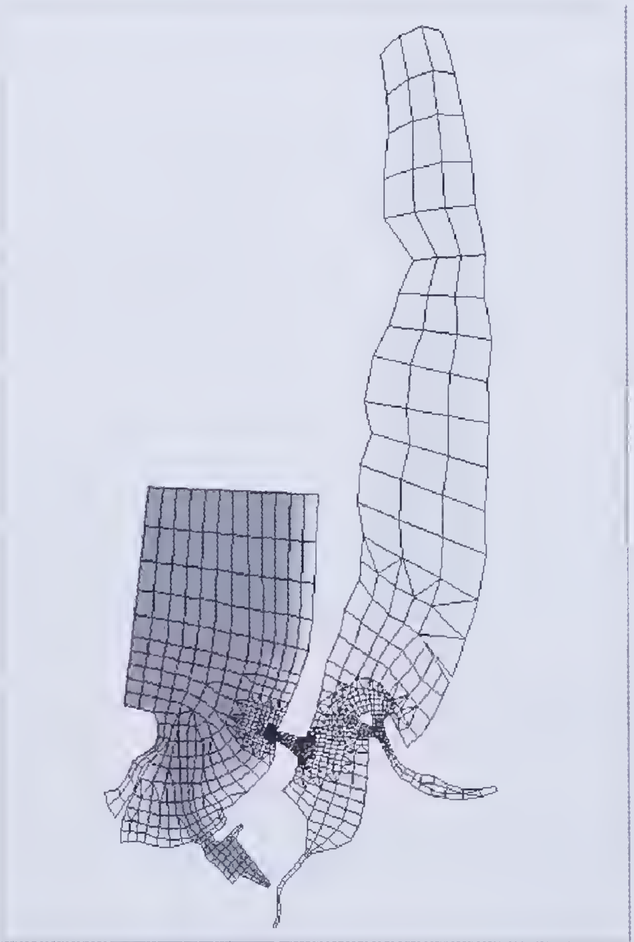


Figure 1. The finite element network used in the mathematical modelling of Leschenault Inlet and Koombana Bay.

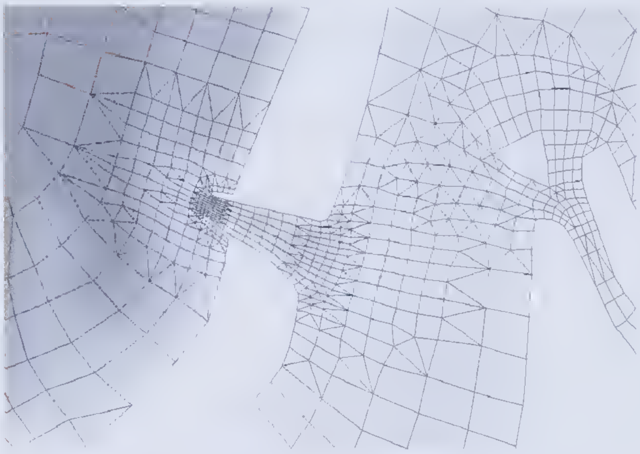


Figure 2. Computation mesh detail at "The Cut", used in the mathematical modelling of Leschenault Inlet and Koombana Bay.

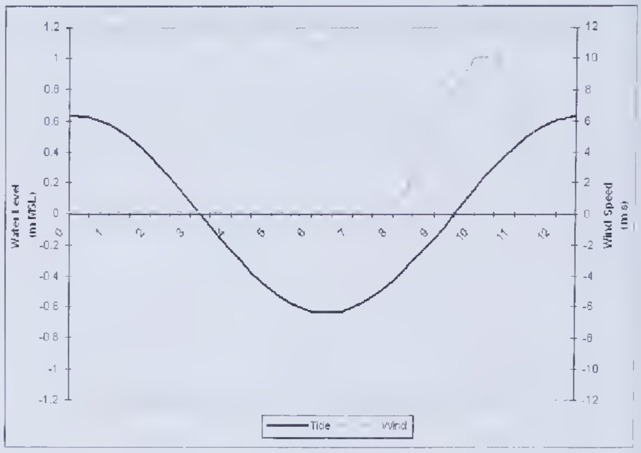


Figure 3. Tide and wind boundary conditions over a tidal cycle of 12 hours.

ent for a semidaily tide, O1 = main lunar constituent for a daily tide, K1 = soli-lunar consituent for a mainly fortnightly constituent) for the Port of Bunbury, just south of Leschenault Inlet (Anon 1997). The port is influenced by predominantly diurnal tides (one tide per day) with a mean spring tidal range 0.5 m. A slightly higher than mean spring tide has been used for all short period simulations with a tidal amplitude of 0.3 m about mean sea level. Additionally, the four main constituents from Bunbury (M2, S2, O1, K1) have been used to generate a long period of tides to assess the effect of the spring and neap tidal ranges on water levels in Leschenault Inlet.

Flows in the tributary rivers were determined by review of river flow records over the period 1985-1995. Table 1 summarises these data. The adopted flow for modelling purposes is approximately the 90 percentile value to allow investigation of typical higher flow conditions.

The influence of the afternoon sea breeze on circulation patterns in Leschenault Inlet is included. A 20 kt (10 m s^{-1}) southwest wind is simulated and is timed to coincide with the rising tide in Koombana Bay. Fig 3 shows the wind speed and tide track over a tidal cycle.

Results

A long term model simulation of 900 hours (37.5 days) was conducted to examine the effect of spring and neap tides on water levels in Leschenault Inlet. Tidal boundaries were generated from constituents as described above and "summer" flow conditions were adopted for the tributary rivers. Fig 4 presents results from the ocean, southern, mid and northern Leschenault Inlet for this long simulation. The mean water level in the inlet is higher during spring tide than during neap periods. In effect, the spring tides "pump up" the mean level in the estuary to a maximum of about 0.06 m above mean sea level while during the neap periods the mean level falls to a low of about mean sea level. Mean water level in Leschenault Inlet is around 0.03 m above mean sea level. During winter, higher river inflows tend to increase this mean level to around 0.10 m above sea level (dependent on river flow). Fig 5 shows results from the summer simulation. Water levels in the inlet and ocean are plotted along with current velocity through "The Cut".

These model results indicate a significant attenuation of the ocean tidal range in the inlet as well as a 4- to 7-hour phase lag for high and low water between the ocean and the inlet. These characteristics are a consequence of the hydraulic restriction presented by "The Cut". Peak flood tide velocities in "The Cut" occur about 1-2 hours prior to high water in the ocean and peak ebb velocities about 2-3 hours before low water in the ocean. Flood and ebb tidal flows in "The Cut" continue on for several hours after ocean high and low water respectively. Figs 6A-6D show circulation patterns in Leschenault Inlet under the influence of summer and winter river flows (respectively). Figs 6E-6F show the circulation patterns during summer with the additional influence of the afternoon sea breeze coinciding with the rising ocean tide as described above. A comparison of the model results indicates that the circulation patterns in Leschenault Inlet are very similar for summer, winter and the summer breeze condition. However, circulation patterns in Koombana Bay appear to be quite different. The eddies observed are set up by the ebb tide jet through "The Cut", the strength of which is dependent on the tidal range, wind conditions and river flow conditions. The existence of these eddies is unconfirmed, and their presence has little hydrodynamic influence on circulation patterns within Leschenault Inlet.

Numerical modelling of Leschenault Inlet and Koombana Bay indicates that Leschenault Inlet is influenced by a predominantly diurnal tide (one tide per day). A delicate balance of forces governs water movement in the Bay, "The Cut" and lower inlet (van Senden 1987) in-

Table 1. Summary of River Flows for the Collie, Brunswick, Preston and Ferguson Rivers (1985 to 1995)

		Flow		
		Average	90 Percentile	Adopted
Brunswick &	January	7.8	10.2	60.7
Collie Rivers	July	28.6	60.7	60.0
Preston &				
Ferguson	January	0.2	0.3	0.5
Rivers	July	13.9	29.9	30.0

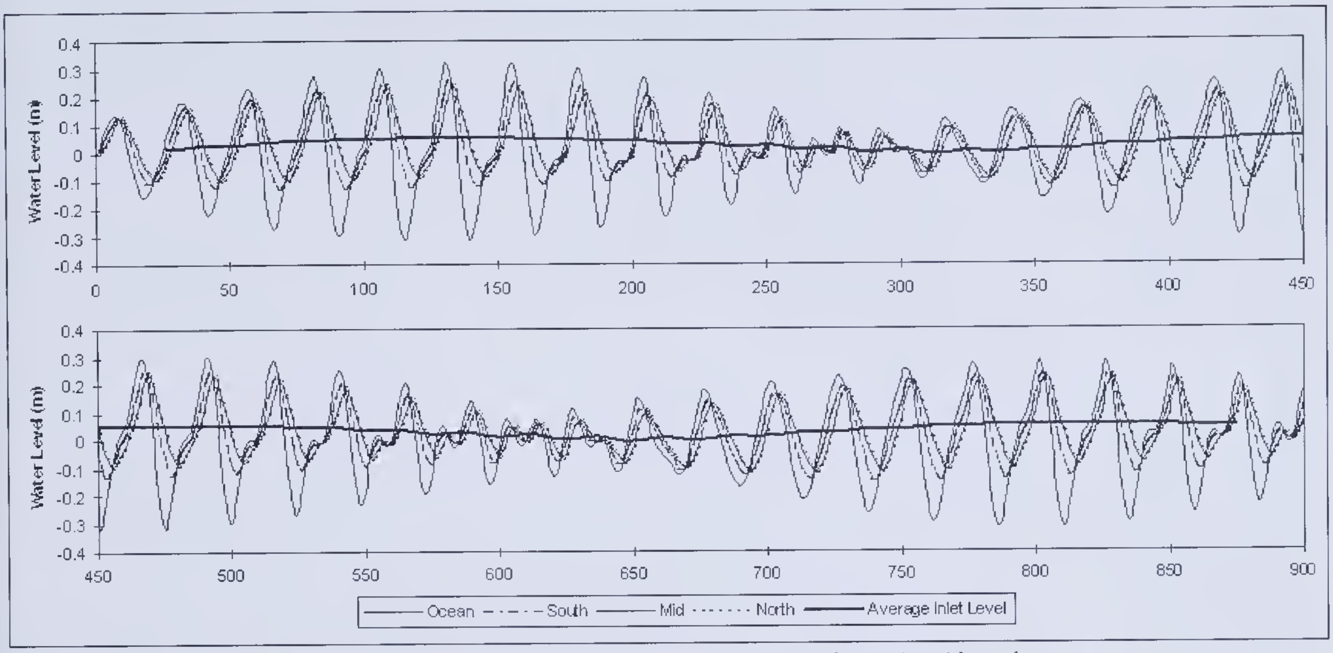
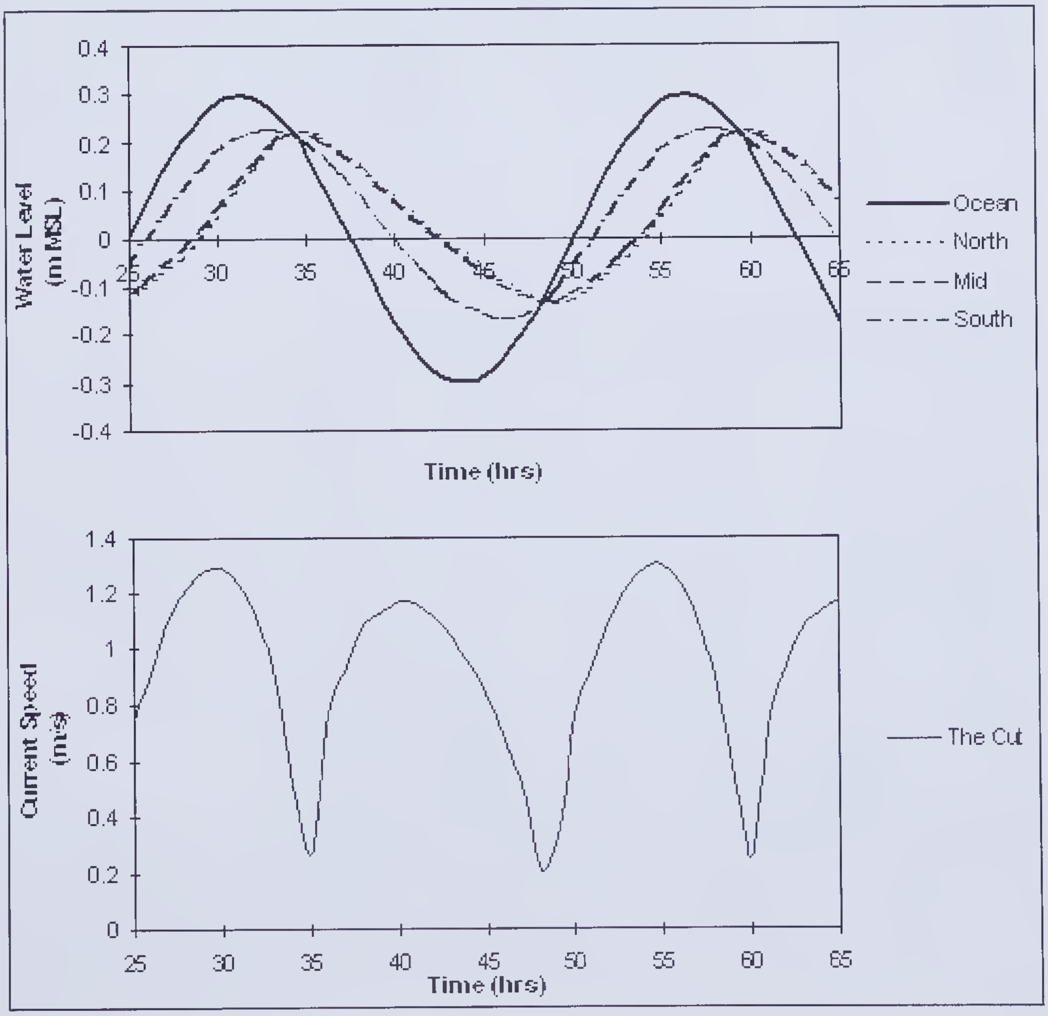


Figure 4. Mean water level variation in Leschenault Inlet over a spring tide - neap tide - spring tide cycle.

Figure 5. Flow characteristics at "The Cut" for a summer simulation. Water levels in the inlet and ocean are plotted along with current velocity through "The Cut".



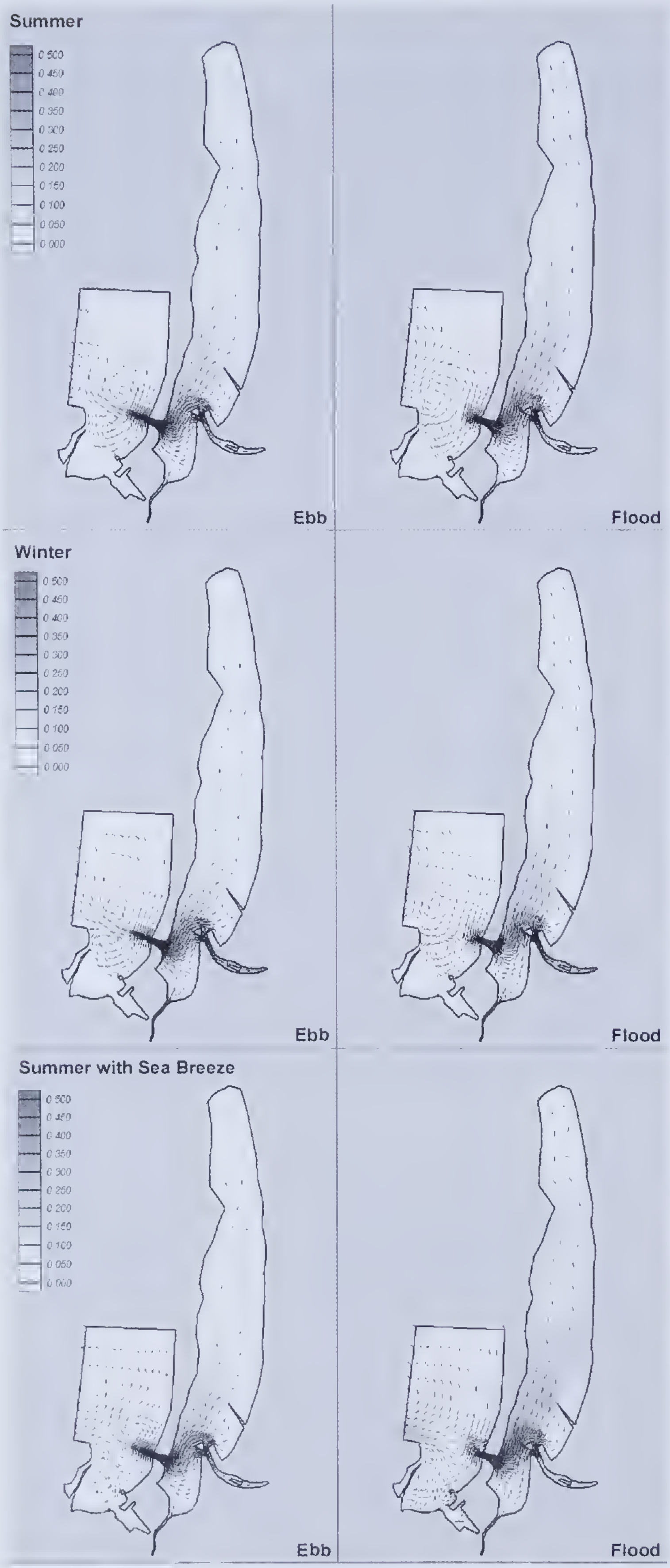


Figure 6. Circulation patterns, ebb and flood tides, for summer versus winter conditions, and summer conditions with a seabreeze. Arrows indicate direction of current. Graded shades of grey indicate magnitude of current m s^{-1}.

cluding surface wind stresses, buoyancy and momentum fluxes from "The Cut", currents induced by sea level changes, bottom friction and inertia forces due to topographic constraints. The balance of these forces has been found to vary seasonally.

Peak flood tide velocities in "The Cut" occur about 1-2 hours prior to high water in the ocean. Peak ebb tide velocities in "The Cut" occur about 2-3 hours before low water in the ocean. The mean water level in Leschenault Inlet varies and reaches a high of about 0.06m above mean sea level following a period of spring tides. Mean water level at about mean sea level occurs in the inlet following a period of neap tides. Mean water level in Leschenault Inlet is also influenced by river flow and is generally higher during the winter months when flows from the Preston, Ferguson, Collie and Brunswick Rivers are higher.

Circulation patterns in the inlet are similar for summer and winter conditions. The afternoon sea breeze appears to have only a minor effect on circulation patterns in Leschenault Inlet. The circulation patterns would result in a strong component of transport of suspended sediment that would move to the prograded supratidal flats to the far north. This northerly movement of sediment is evident as northerly directed spits and other sedimentologic factors described elsewhere in this volume.

The simple two-dimensional model described here used a coarse representation of bathymetry in the Inlet. Inclusion of a detailed bathymetry may make some difference to predictions because of the large shallow expanses along the eastern and western margins of the estuary. The magnitude of these differences is not expected to be great and is unlikely to greatly alter the circulation patterns described here.

References

Anon 1997 Australian National Tide Tables. Commonwealth of Australia.

King I P 1997 RMA2 - A Two Dimensional Finite Element Model for Flow in Estuaries and Streams.

van Senden D 1987 Dynamics of unsteady jets in shallow receiving waters. PhD Thesis, Department of Civil Engineering, University of Western Australia, Perth.